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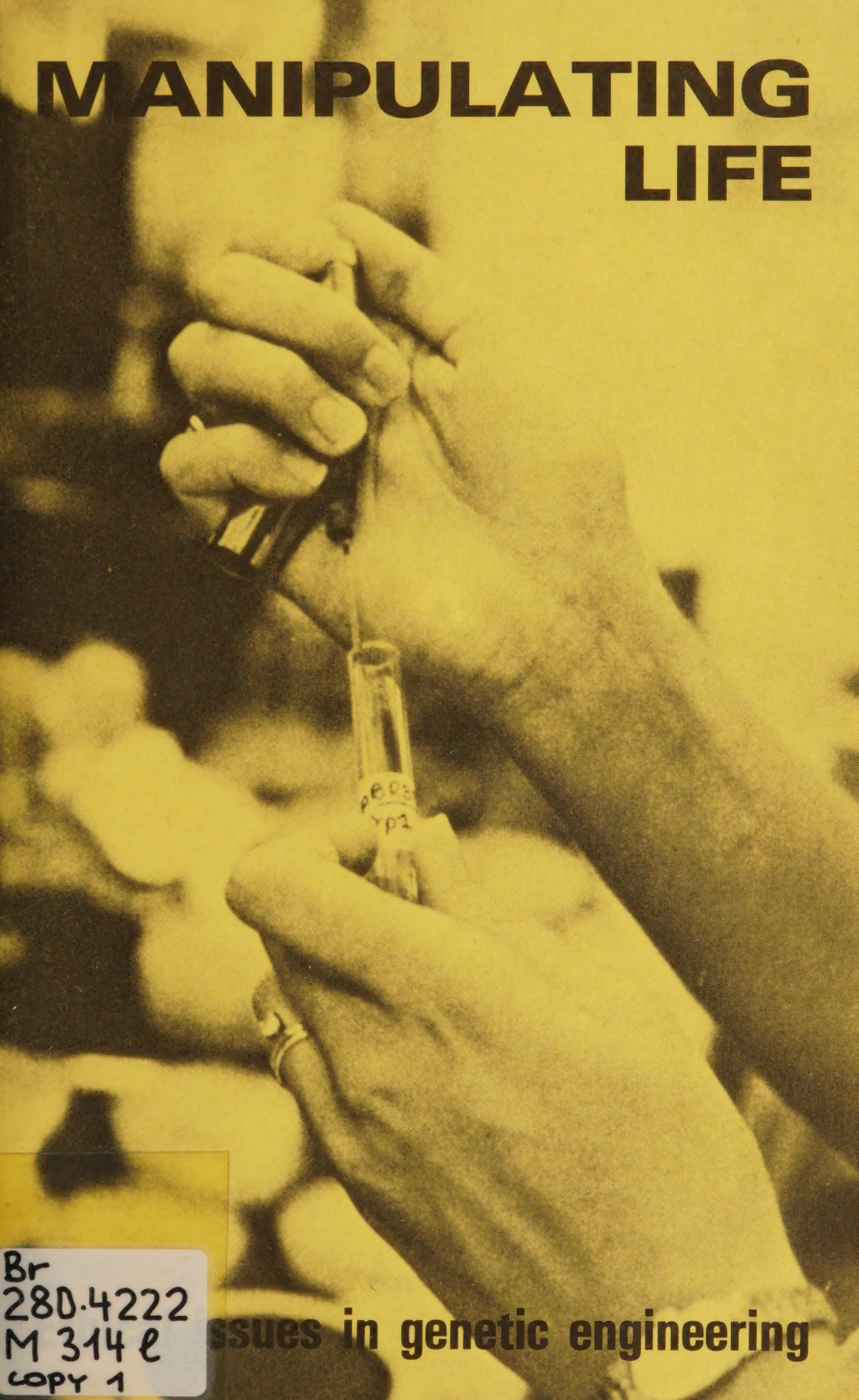

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Manipulating life

Ethical issues in genetic engineering

Church and Society
World Council of Churches, Geneva

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Preface

In 1971 the World Council of Churches began to take an interest in the ethical and social problems arising from developments in the biological sciences. This led to the first ecumenical consultation on "Genetics and the Quality of Life", held in June 1973 in Zurich.[1] The meeting focused on issues of genetic counselling especially in view of new techniques for foetal diagnosis of genetic defects. During 1974 and 1975 the report of the consultation was circulated to churches as well as to scientists and technologists involved in human genetic research, and it provoked follow-up discussion in many churches and national councils of churches. It was also discussed in one section of the WCC Assembly in Nairobi in December 1975.[2]

The Nairobi Assembly recommended that as part of the proposed Church and Society programme on "The Contribution of Faith, Science and Technology in the Struggle for a Just and Sustainable Society" there should be further attention to the "ethical dilemmas arising from the application of modern biology to human problems". The topic was subsequently added to the list of subjects to be taken up by the world conference on "Faith, Science and the Future" at MIT in 1979 and became the theme of one of ten sections into which the work of the conference was divided. The report of that section, "Ethical Issues in the Biological Manipulation of Life", contained a series of recommendations on the follow-up, including proposals for a working group on the benefits, threats and hazards of human genetic engineering.

In June 1980 the Working Committee on Church and Society recommended to the Central Committee that such a working group

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1. See Charles Birch and Paul Abrecht, *Genetics and the Quality of Life*, London, Pergamon Press, 1975.
2. See *Breaking Barriers, Nairobi 1975*, Geneva, WCC, 1976, p. 128.

be formed and in a further statement of its own the Committee suggested some priority concerns. The WCC Central Committee approved this plan for a working group whose purpose would be "to advise the churches on the ethical implications and social consequences of the rapid developments in genetic and biochemical manipulation".[3]

The first step was to circulate the report of the MIT conference and the 1980 statement of the Working Committee on Church and Society to more than 200 biological scientists for comment and suggestions. A number of replies were received, including both favourable and critical reactions. Some scientists protested that the MIT conference report and the 1980 paper from the Working Committee had overstated the risks of recombinant DNA technology.

In the light of these replies it was decided to focus the attention of the working group on "Ethical and Social Issues in Genetic Engineering and the Ownership of Life Forms". A group of scientists and theologians were invited to take part in a meeting held at the International Graalcentrum, de Tiltenberg, in the village of Vogelenzang, Netherlands, 15-19 June 1981. The findings and recommendations of that working group were circulated for comment and reaction to a number of scientists and submitted to the WCC Central Committee meeting in Dresden, August 1981. The Central Committee received the report "with appreciation" and agreed that it "be commended to the member churches for study". It also recommended that a letter be sent to member churches, national academies of science, and specialized agencies of the United Nations calling attention to the recommendations addressed to them on pages 33 and 34 of the report.[4]

The following is the final text of the report as revised by a core group of the Working Committee on Church and Society, June 1982, to take account of suggestions received on the first draft.

Readers of the report will have some hint of the vigorous and often sharp differences of outlook in the initial working group, especially on questions of the risks of genetic engineering, and application of positive eugenics of human life. There was however unanimous agreement that rapid developments in this field and their significance for human life justify the recommendation that there be a more consistent and systematic monitoring by the WCC and the churches of such scientific work.

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3. *Minutes*, Central Committee (Geneva), Geneva, WCC, 1980, p. 49.
4. *Minutes*, Central Committee (Dresden), Geneva, WCC, 1981, p. 68.

1. Introduction

The developments in modern biology have opened up a broad new discussion in many societies of the nature of life and the right use of the new knowledge about human life and other forms of life. The churches are naturally interested in this discussion and indeed are already involved in it. Historic Christian teaching about the dignity of human life and the way this is to be expressed have, for some people, been challenged by such new technologies as amniocentesis, genetic screening, selective abortion, *in vitro* fertilization, artificial insemination, surrogate motherhood and gene transplantation. For the churches this raises two concerns: (1) what shall they teach concerning responsible attitudes and actions on these issues; and (2) how can they come to a better understanding of the meaning of faith in the full light of the new knowledge and power that the biological sciences have brought?

New understanding and new conceptions of life are involved. However, the initial reactions of some churches have been ones of fear, distrust and even calls for prohibition of these new developments. This has gone along with attempts to affirm even more strongly outdated doctrines of creation, such as an interpretation of the first chapter of the book of Genesis as a scientific account.

The creative response to this new knowledge will be one that leads to a deeper understanding of the nature of life and of human responsibility for life. The Christian church is challenged to help ensure that human life is enriched and human society is made more whole. This is no small challenge. It requires study and reflection on the new knowledge that biology brings, and the working out of the relation between faith and this knowledge to an extent we have as yet hardly begun.

This is indeed the challenge of the theme of the next WCC Assembly: "Jesus Christ — the Life of the World". The theme displays

the possible interconnectedness and unity between the scientific and the Christian approaches to understanding the life of the world. The present tendency of science and technology is to separate things from their philosophical underpinning so that they become sources of yet more splintering of the knowledge of the world. And theology instead of manifesting the Christological unity as it relates all the fragments has too often presented itself as one of the fragments alongside others. The theological task ahead is to make sense of the claim that Christ is the unity of all life in the light of the new knowledge.

2. Human genetic engineering

Biological scientists have in recent years made extraordinary progress in analyzing the functions of cells and tissues and the molecules that constitute them. The most striking of these advances has been the development of recombinant DNA technology which permits the splicing together of the genes from unrelated organisms and their introduction and reproduction within living cells. These technologies are the result of many years of public investment in biological and biomedical research, much of it in pursuit of the goal of improving public health and welfare. Human genetic engineering opens up new scientific, social and medical possibilities:

a) a rapid increase in the rate of accumulation of knowledge about the genes of humans and other organisms;
b) the possibility of altering the genetic constitution of human beings (perhaps remote) and other organisms.

Some of the recent advances in molecular biology have been so startling as to awaken anxieties in the wider population. New technological capabilities have raised troublesome questions about their uses and misuses.

Ambiguities line the road ahead and there is the possibility of error on all sides. However, if science and technology are to serve the welfare and fulfilment of the broader human society, we must maintain continued discussion, dialogue and debate on all aspects of these powerful new technologies. Of special concern is the reality that the inequitable distribution of power, influence and knowledge increases the possibility of the misuse of technology.

A. Likely applications of genetic engineering to human beings

The functional units of genetic information are the genes, each of which specifies a polypeptide from which proteins are built. Every

human cell has the genetic capacity for the production of at least 10,000 different proteins. The distinguishing feature of the various types of cells in the human body is that they each produce a different subset of these proteins. For example, cells in the eye produce a different set of proteins from cells of the muscles.

In a genetic disease such as sickle-cell anaemia there is a defect in a gene which in this case manifests itself in the production of defective hemoglobin (an essential protein of the blood). An aim of human genetic engineering in this case would be to supply the individual with a normal version of a gene. This prospect is still in the future but below we examine some of the more immediate possible applications of genetic engineering to humans.

1. Therapeutic use of genetic engineering by introduction of DNA into body cells

Genes are composed of a substance called DNA. Genetic engineering, as a therapy for genetic disease, involves delivering the appropriate non-defective DNA molecule for integration into the cells of the body (somatic cells) which are manifesting a genetic defect. Unlike drug therapy this could offer a permanent cure for the patient.

All current methods of administration of DNA to living organisms are unable to direct the DNA to a specific population of cells within the body. The use of any technique of introducing DNA that is not completely specific in terms of the cells affected would have to take into account the possibility of affecting the germ-line (sex) cells of that body.

An alternative approach would be to remove cells from the body, carry out gene therapy and then return the cells to the body. This method has already been used in an experimental attempt to treat two patients having the genetic disease beta-thalassemia (another hemoglobin defect). Some cells were removed from the patients' bone marrow. DNA specifying the normal protein was introduced and the cells were returned to the patients, whose other bone marrow cells had been destroyed. This attempt was clinically unsuccessful. This first case was, in fact, not sanctioned by appropriate review committees and has been censured for violating regulations on research.

2. Genetic engineering of the germ-line (sex) cells

The introduction of DNA into germ-line (sex) cells differs from the correction of a genetic defect in somatic cells in that the correction would be passed on to subsequent generations. Technically one

would have to envisage delivering DNA specifically to all the germ-line cells of an individual carrying a defective gene. This has recently been achieved in mice in which an egg was fertilized *in vitro* and then modified with foreign DNA prior to transplantation into the mother's uterus. The source of the DNA was a rabbit in one experiment and a human in another.

Prenatal diagnosis involves a variety of techniques; the principal one is amniocentesis in which fluid containing foetal cells is removed from the amniotic sac during the early part of the second trimester of pregnancy. Techniques are also being developed for obtaining foetal cells from a sample of the mother's blood. Cells obtained in this fashion can at present be used to detect the existence of only a limited number of genetic conditions, e.g. Down's Syndrome or Tay-Sachs disease where large abnormalities in the genetic constitution of the foetal cells or abnormalities in the biochemistry of the cells allow a diagnosis to be made. But recombinant DNA techniques applied to prenatal diagnosis open up the possibility of diagnosing most genetic conditions. In this case the technique is to create gene "probes" which can identify whether a normal gene or an abnormal variant is present. Furthermore, other recombinant DNA techniques still in their early stages of development will permit the "mapping" of human genes, so that a particular gene of clinical interest may be located by its association with another "marker" gene. These techniques would provide the possibility of identifying *any* gene in foetal cells, not merely those for which tests of abnormal products exist. Thus the techniques raise the possibility of prenatal prediction of all sorts of properties of the growing foetus, in addition to the presence of genetic disease.

B. Ethical and social problems and possible social controls on experimentation

Many of the social and ethical issues that arise in debates about genetic engineering have less to do with genetics than with broader questions of human good. There are, to be sure, some quite specific ethical questions about genetic practices: should certain operations be encouraged or discouraged, permitted or prohibited? But even these questions are usually rooted in more comprehensive questions of meaning and purpose in human life. Because genetic engineering brings new human power, it raises to new importance many old questions about the use and direction of power.

1. Alterations of particular somatic cells

Attempts to alter the genes of particular cells in individuals who suffer from recognized diseases of genetic etiology are comparable to other forms of experimental therapy. Accordingly, they should be undertaken only when necessary because other forms of adequate treatment are unavailable and only with the usual protection for human subjects of research. These include the requirement of the informed consent of the patient-subject or a proper substitute decision-maker and prior approval of the experiment's scientific and ethical merits by appropriately constituted bodies. Prior to commencing such an experiment, it would be desirable to have an understanding of the means by which new DNA will be incorporated into the cells, be regulated and be expressed.

So long as genes were unalterable, the burdens that genetic endowment imposed may have been unfair, but they were at least not injustices of the type that result from any human agency. The ability to alter human genes changes this. Henceforth, the choice to alter one gene but not another will become a matter requiring ethical justification. The community may well agree that certain conditions are so deleterious as to deserve first call on resources of genetic engineering. Beyond these polar cases, however, choice about genetic engineering becomes a matter of subjective judgment which will differ according to personal values.

2. Alterations involving germ-line cells

Graver concerns would be raised were changes to be brought about in the DNA of germ-line as well as somatic cells, as then not only is the individual changed but all descendents, in perpetuity. The possibilities for intervention in human heredity extend to qualitative changes involving the biological manipulation of human life which goes far beyond therapy for genetic disease. Whether anything like this will ever be done is largely a social and political issue. A dictator now has new and more refined tools at his disposal to add to the means already tried in our own generation.

a) Ethical issues

1. When the pain of another person can be relieved or avoided, doing so is usually counted as a good; indeed, in most circumstances, failing to do so would be regarded as a moral wrong. Thus, somatic cell therapy may provide a good; however, other issues are raised if it

also brings about a change in germ-line cells. The introduction of genes into the germ-line is a permanent alteration. The basis for a decision to carry this out would require a detailed knowledge of any other possible genetic consequences of this manipulation. There would be a real problem of deciding when sufficient information was available to make a decision whose genetic consequences would continue into a future that may be very different from today. Nonetheless, changes in genes that avoid the occurrence of disease are not necessarily made illicit merely because those changes also alter the genetic inheritance of future generations. By overcoming a deleterious gene in future beings, the beneficial effect of such changes may actually be magnified. It is of course true that mutation in the sex cells involves a change in the germ-line. This is going on all the time. At least 10% of all human fertilized ova (zygotes) contain one mutant gene not present in either parent.

2. The considerations about justice discussed in B.1 above would be presented with even greater force were it possible to alter genes in a developing zygote or embryo. There is no absolute distinction between eliminating "defects" and "improving" heredity. Correction of mental deficiency can move imperceptibly into enhancement of intelligence, and remedies of severe physical disabilities into enhancement of prowess. Values then become highly controversial.

3. In such circumstances the possibility is presented of enhancing the future child's potential rather than merely correcting specific defects. For some parents, the absence of certain desired traits in their offspring may seem as great a burden as the presence of medically defined "defects" seems to others. It is the responsibility of the scientific community and other knowledgeable people to disabuse the public of the notion that such "positive" traits can at present be identified genetically, much less supplied at will in individual cases. More fundamentally — against the day when the capability for "positive" genetic engineering may be at hand — people should be encouraged to examine, in the light of ethical and religious beliefs, whether the use of such capabilities would be desirable. The transformation of procreation into a laboratory science and of offspring into products with interchangeable parts to be selected at will would bring about a major change in human self-understanding.

The central concept of the human person as irreducible to its parts and the repository of an inalienable dignity has a close but very complex relationship with our ideas of liberty, responsibility and justice.

A view of humanity as an object to be manipulated may reduce the mutual respect of people for each other and consequently increase the risk of additional exploitation of people by people.

Like other techniques of modern science, genetic manipulation amplifies and accelerates the tendency towards total reductionism. First, it helps to generate new knowledge about the physical basis of inheritance to which existing philosophical systems must adapt. Second, if practised directly and deliberately on human beings, genetic engineering converts the human subject into a composite object of interchangeable elements. A threat to the conception of humanness may be as important as any possible adverse physical consequences of the technology.

Although the magnitude of such ethical and social consequences of increased genetic knowledge and of human genetic engineering is uncertain, they are so far-reaching that public discussion of them and public decision on effective ways to deal with them are essential. Such discussion should enable mankind both to develop existing systems of thought to deal with the new genetic knowledge and also to consider what limits should be set on genetic manipulation.

Many ethical and religious traditions endorse some human freedom to modify or transcend nature. But for us to change *substantially* the germ-line DNA is to directly alter the genetic foundations of the human. In what ways do we, by manipulating our genes in other than simple ways, change ourselves to something less than human? If we accept this power, do we have the wisdom to use it?

4. An increase in the means for achieving health and wellbeing is ethically desirable. It is important to assure, however, that new options do not become new dogmas. The choice to avoid a genetic condition in one's offspring by means of a germinal cell change should not become a legal requirement that such changes be made. Prospective parents are owed a full and informative explanation of the means available for promoting the genetic health of their children, as they see it, but neither society nor the medical profession ought to insist on a particular course of genetic engineering. Limitation of parental choice is acceptable, however, when needed to protect a child or child-to-be from an intervention known to be overwhelmingly harmful.

b) Social issues

1. There are genetically transmitted human characteristics that some societies have made into social liabilities. When a society makes

skin colour a social or economic advantage, the problem is not one of changing genes but in changing social values and prejudices. The need is not to modify the genetic inheritance of people, but to examine and revise the dominant values of the society. The history of eugenic movements, from Plato to the present day, shows many examples of individuals and groups, including scientific leaders and often so-called experts, who institutionalized their prejudices of race, sex and class through programmes that caused tragic harm. Those prejudices are morally offensive, quite apart from genetics. It is important today to ask of every genetic proposal: what human purposes and desires does it project? Whom does it benefit and whom does it hurt?

2. The understandable biomedical interest in correcting genetic defects should not divert attention from the need to attend to non-genetic diseases, to protect human genes from avoidable damage (from mutagens, carcinogens and man-made radiation) and to provide each person with the opportunity to develop his or her existing capabilities.

3. Although the prospects for genetic manipulation are at present limited to single-gene defects with severe manifestation, societies should be prepared to deal with attempts to extend the genetic techniques to other traits that have a more complex genetic basis, or to behavioural traits, where the degree of genetic determinism is largely unknown. Any decision about the wisdom of deliberately modifying such traits in the distant future should be postponed until more adequate knowledge is available. Nevertheless, extensive public discussion on the wisdom of allocating resources to the acquisition of the requisite knowledge to be used for this purpose is highly appropriate and should be encouraged.

4. More immediate concerns arise from the fact that even if such manipulation is generally considered premature, there may be no legal barrier to its use by individuals. Particular attention should therefore be given to legal safeguards designed to protect individuals and their potential descendants with respect to (a) quality control of the materials and methods used, and (b) misrepresentation of possible benefits by commercial advertisers or by scientists testing new methods or materials. The lack of control over artificial insemination and especially over sperm banks is indicative of the problems that may arise. Societies that commercialize most achievements are likely to do the same with accomplishments alleged to have a genetic basis.

The fascination with a sperm bank donated by Nobel laureates and the fact that it has been used demonstrate this. It may be followed by commercial operations retailing the semen of athletes and other well-known figures. Genetic engineering offers the prospect of inserting selected genes from such individuals, rather than their entire genotype.

5. To the extent that parents may become able to prescribe the genetic inheritance of their children, what traits will they choose: superior intelligence, artistic capacity, good looks (by the criteria of a particular society), athletic prowess, aggressiveness? If a nation could shape the genetic qualities of a future generation, would it seek to produce super-warriors? If a government could influence the genetics of a people, would it seek to produce conformists readily submissive to authority? (Already parents, churches, nations and governments try to do some of these things through educational means and selective information.) The possibility of genetic engineering raises the issues in new forms.

6. A community should be deliberate about its allocation of funds to research, both fundamental and applied, and to health care services. If societies in the past had not supported fundamental research the world might still be suffering from smallpox. But as research gets more complex and expensive the issue of its funding and the distribution of its benefits gets more complex. This calls for yet more deliberate decisions in the way funds are allocated. Genetic engineering thus raises the issue of the distribution of funds for health care.

c) Control of experimentation

1. All genetic engineering techniques are at the moment highly experimental. There is great need for careful and dispassionate evaluation of each proposed experiment, especially when the desperation of a patient's condition might lead to the trying out of unproven techniques of dubious efficacy.

2. Special difficulties are posed by any experimental methods that involve the manipulation of zygotes or embryos. The concern here exceeds that which would normally attach to experiments with anyone unable to consent for oneself (e.g. a young child).

* * *

Many of the problems of human genetic engineering discussed here are of an unprecedented nature. The implication of this for ethical judgments by churches was acknowledged in an earlier ecumenical report:[1]

> Churchmen cannot expect precedents from the past to provide answers to questions never asked in the past...Ethical decisions in uncharted areas require that scientific capabilities be understood and used by persons and communities sensitive to their own deepest convictions about human nature and destiny. There is no sound ethical judgment in these matters independent of scientific knowledge, but science does not itself prescribe the good.

Even so, many of the social and ethical issues related to the new genetics are perennial human issues, newly thrust into prominence and dramatized. Although it is certainly appropriate to give attention to specific issues of genetic practice (whether now operational or projected), such attention should not displace, but ought rather to reinforce, concern for the broader questions of justice, human purpose and the quality of life.

Recommendation

These issues place new responsibilities on review committees on human subjects which have been set up in hospitals to ensure that people who agree to be the subject of medical experiments are fully informed of all possible negative effects, and also on national committees with advisory or regulatory responsibilities for genetic engineering. Too often, membership of review bodies has been dominated by those with interests in the promotion of the techniques under consideration. The best protection of the rights of human subjects of genetic engineering will be to ensure adequate participation in decisions by those affected. In issues bearing on eugenics and reproduction there is special need to involve women and minorities in the decision-making process. We request the Central Committee to invite the churches to examine how they can contribute to this human subjects' review process, and to the work of national regulatory committees with respect to genetic engineering.

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1. Charles Birch and Paul Abrecht *Genetics and the Quality of Life*, London, Pergamon Press, 1975, pp. 200-223.

3. Risk of recombinant DNA technology

The rapidly advancing recombinant DNA technology should be viewed in the perspective of past experiences of society with new technologies. The history of the introduction of new technologies into human societies is replete with examples of unforeseen deleterious consequences affecting *particular* groups of people or environments. The development of the textile industry resulted in the introduction of chronic lung disease (byssinosis) in factory workers as a result of exposure to cotton dust. Many employees in the aniline dye industry suffered from bladder cancer. The uncontrolled dissemination of pesticides has resulted in major losses of marine life. These effects were not discovered until long after the initial introduction of these technologies. Even in the pharmaceutical industry, in which systematic testing for side effects has been practised, major disasters have nonetheless occurred, such as the induction of birth defects by Contergan (Thalidomide). Although technologies such as these delivered both benefits and risks, the latter were not distributed equitably.

A. The debate about the hazards of recombinant DNA technology

The development of recombinant DNA technology in the mid-seventies triggered a sharp debate in the scientific community over the potential health hazards associated with this technology, a debate which initially restricted itself to the laboratory context. At first the technology involved the insertion of foreign DNA molecules into a laboratory strain of the common intestinal bacterium *Escherichia coli* (called K 12). Since these bacteria are relatives of organisms known to cause human disease, the introduction into *E. coli* of genes which specify biologically active proteins, such as insulin or human growth hormone, raised the possibility of the generation of novel forms of human or animal disease. In addition, the foreign DNA is

often linked to bacterial plasmids (small DNA molecules residing in bacteria along with the chromosomal DNA). Many of the plasmids used confer resistance to antibiotics, which increased concern about the possibility of their selective increase and dissemination in the environment should they escape from the laboratory. Of special concern was the possibility that after escape, the recombinant plasmids might become associated with strains of bacteria that cause disease.

Concern with the potential human and environmental health hazards from pollution by genetically modified organisms has lessened considerably in the last year or two, due to (a) further experience with recombinant DNA technology, (b) the development of guidelines and procedures for carrying out the research, (c) development of physical and biological containment procedures (i.e. the use of enfeebled host strains) to minimize release or survival in the environment, (d) the assessment that *E. coli* K12 strains are themselves unlikely to survive in the human gut or the environment, and (e) the assessment that genetically engineered organisms are at a selective disadvantage compared to naturally occurring organisms.

As a consequence of these arguments it is now generally claimed by molecular biologists that the risks of recombinant DNA technology are minimal. This development has removed one of the main barriers to the commercial exploitation of the technology.

Recombinant DNA technology is now rapidly moving from the laboratory bench to the factory with a great variety of potential applications. The historical experiences described above, relating to the introduction of new technologies, suggest that the emerging biotechnology industry, like other industries, will have its own forms of pollution and unforeseen side-effects. The operations of a factory with 100,000 litre fermenters of micro-organisms synthesizing mammalian proteins, day after day, year after year, pose problems not encountered in laboratory manipulations. In addition, certain environmental and agricultural applications envision the direct introduction of genetically modified organisms into the ecosystem, for example, oil-degrading bacteria.

In particular, we note two qualitative differences between potential bio-pollution, and pollution from conventional production processes. Oil spills, chemicals and radio-active substances do not reproduce themselves; engineered organisms may. Some fraction of the genetically altered micro-organisms released into the environment, by accident or intent, may establish themselves in some unexpected niche.

Second, once established they may continue to evolve in unpredictable directions. If any of these organisms turns out to be deleterious to humans or other creatures, by the time this is discovered, it will probably be too late to eliminate them from the environment.

Though many scientists involved in these technologies disagree with these assessments, we do not believe that survival and risk assessment experiments carried out on one strain of *E. coli* can accurately serve to predict the behaviour of the great variety of genetically modified organisms that can be expected to be generated in future applications of recombinant DNA technology. In addition the pressures of commercial exploitation may well undercut the application of guidelines carefully developed in the academic context.

In the initial debate over potential hazards of recombinant DNA technology, the most dramatic scenario was the possible spread of a novel infectious agent throughout populations. However, in industrialized countries the development of sanitation and hygiene has largely removed the conditions necessary for epidemic spread of most bacteria. Since the genetic modifications are of limited extent, we do not believe that epidemic spread is a realistic concern. On the other hand, within the developing nations many "conventional" bacterial infections remain major human health hazards whose epidemic spread is still common. In these settings extra care with respect to genetically modified organisms will be required, for example the use of enfeebled host organisms may be suggested.

B. Programmes of assessment of risk to health and to the environment

The process of assessment of risk to health and to the environment should be an integral part of the development of any technology. It should develop together with the technology itself, so as to continually maximize the beneficial contributions, and limit negative impacts. This can only be done through mechanisms that involve all affected and interested social groupings at all levels of the assessment process. Such assessment should not be limited to the early stages of development of these new technologies, but it should become a continued and ongoing programme. Some information is only available after certain lengths of time and repeated or continued contact with certain substances. Research in the early stages of development cannot foresee all of the side-effects of new technologies: long-range or chronic effects are often visible only to later investigation. It seems

therefore crucial that ongoing programmes of research and review become established and promoted as both scientifically valuable and socially necessary. There are at least two obstacles to this type of research:

1. Industrial scientists are often hindered by their employers in their research into the health and safety of the workplace. There are documented cases of industrial scientists who felt compelled to seek other employment because of research findings that would have mandated health and safety changes which would have increased production costs for the industries in which they worked. To protect these scientists and other industrial employees who are concerned about safety and health, procedures need to be established that require the reporting of adverse health or environmental effects of biotechnological processes or products. Such reporting should be to both employer and the public agencies and committees responsible for monitoring these technologies.

2. Research into occupational diseases associated with the products and processes of new technologies has sometimes been given a lesser status than other types of scientific and medical research. Scientists who choose research goals having to do with the health side effects of industry and technology should be rewarded comparably to those pursuing other medical problems.

C. Participation

The process of decision leading to development as well as the ongoing systematic review requires the participation of those people who are most likely to be affected or "at risk".

There are two basic factors undergirding the concept of participation: an ethical principle and the knowledge generated and experience provided by those most closely involved in the process.

1. *The ethical principle:* We affirm the fundamental human right of people to be involved in decisions affecting their wellbeing. This right has been explicitly enunciated in the concept of informed consent in medical experimentation and medical treatment as specified in the Nuremberg Code. One of the requirements of the just, participatory and sustainable society is full participation of its members in decisions affecting their wellbeing and the environment. It follows that the same right applies to workers involved in the production of genetic materials, to communities and to societies who may be "at risk" as the result of genetic developments.

Participation should include access to information, input of information and collaboration in policy-making. To ensure participation, specification of population, vocational or interest groups "at risk" in particular situations needs to be made. Some participatory mechanisms merely give the illusion of participation.

2. *Benefits of participation:* Individuals or groups who will be affected or who are at risk may be able to contribute valuable knowledge that will enhance the effectiveness of any proposed procedures. Their contribution may take the form of knowledge of a technology, a procedure, the character of the particular workforce, or of the social or environmental consequences of certain processes.

It may also include certain experiences and religious and cultural perspectives that can help direct the development of these technologies, experiences and perspectives that might be excluded in a purely technical discussion of the issues.

D. Special concerns

1. In light of the foregoing we affirm the desirability of regulatory control of recombinant DNA technology at all institutional levels, but with special emphasis on the commercial sector and large-scale operations:

a) to ensure adequate knowledge about potential risks on a continuing basis;
b) to ensure participation of representatives of all segments of the affected population or interested groups in all stages of the procedure;
c) to ensure the establishment of appropriate health monitoring procedures for the facilities and communities where these technologies are developed and used;
d) to promote mechanisms that provide sufficient monitoring of the effluent from the enterprise in order to avoid situations experienced with chemical waste.

2. Adequate protection for third world countries is necessary to:

a) prevent the type of problems that have been associated with the testing of new pharmaceutical products and the marketing of ones disapproved in industrial countries such as the testing of the contraceptive pill in Puerto Rico and the marketing in third world countries of certain intra-uterine devices and drugs banned in the industrialized countries;

b) ensure that therapies or products produced fit the local, cultural, economic and social needs;
c) protect against social impacts that tend to promote dependency rather than self-reliance.

Recommendations

1. We recommend that the Central Committee of the WCC request Church and Society to take the necessary steps to encourage the appropriate agencies of the UN, including WHO, ILO, UNEP and UNESCO, to convene a conference to initiate the formation of international guidelines and regulations governing the development and use of biotechnologies involving recombinant DNA technology.

2. We recommend that the Central Committee call upon the churches to work nationally and internationally to encourage mechanisms of participation that include affected and interested parties at all levels and stages of policy-making regarding biotechnology.

3. We recommend that the Central Committee call upon the churches to promote:

a) the ongoing health monitoring and risk assessment procedures for communities where these technologies are developed and used, and
b) mechanisms that provide monitoring of environmental effects.

4. We recommend that Church and Society initiate a study with third world scientists and theologians of the spread of biotechnology in the third world to ascertain if therapies and products introduced fit the local cultural, economic and social needs.

5. We recommend that the Central Committee ask Church and Society to maintain an ongoing working group on biological manipulation of life to monitor the rapidly developing field of biotechnology and report their findings to the churches, and report initial findings to the next Assembly.

4. Ownership of living organisms

A. Micro-organisms

The ownership of living organisms became an issue of great moment when the United States Supreme Court decided to uphold the award of a patent on an artificially produced micro-organism. This interpretation of existing US law caused reverberations around the world. It was a signal to researchers and corporate boards of directors, particularly in the United States, but also elsewhere. It was accompanied by a tacit invitation to the US Congress to consider further the legal, economic, social and moral implications of claims to patent rights over life forms, of a kind that will increasingly be made as a result of this decision. It is vitally important that further consideration of such questions by the US Congress, by parliamentary assemblies in other countries, and by other governmental, professional and public institutions be carried on. Five causes for concern are considered here.

First, patent applications are likely to be granted soon for micro-organisms created by genetic manipulation, which contain biologically functional human genes and which synthesize medically useful proteins and similar macromolecules. This may not be significantly different from the granting of process patents for the production of pharmaceutical and therapeutic substances. Nonetheless, some argue that patent protection in this form will allow existing and emergent corporations to make excessive profits out of human suffering, to sustain an unhealthy worldwide dependence on pharmaceutical products, and to ignore real health needs because they offer lesser economic returns (see discussion in Section D, chapter 3).

Second, the possibility of obtaining patent protection, the present imprecision in patent law in this field, and intensity of commercial competition between private concerns make probable a phase of extremely costly patent litigation. This prospect is likely to cause major

distortions in the process of innovation and to restrict the range of products made and the kinds of organizations making them.

Third, it is already clear that the commercial potential of the findings of fundamental research in biology is leading to a curtailment of communication and greater reluctance to exchange new research materials and to engage in collaborative projects. In the longer term the commercialization of research may lead to serious problems in maintaining a fundamental research base, particularly in fields thought to have no commercial significance. Furthermore, while patenting may provide the security to permit discoverers to communicate their findings this is not an instantaneous process. It may actually lead to control over biological material that is incompatible with the traditional free access to scientific information.

Fourth, much of the research leading to commercially valuable knowledge was supported by public funds. Unfortunately, many valuable results have been and will be appropriated as private property, through patents and the like, by corporations and individuals rather than being regarded as public property. Not only does this deplete the public exchequer but the needs of the community might be better served by arranging for the commercial exploitation of publicly funded research by publicly owned corporations.

Finally, the US Supreme Court decision on patenting of life forms rested upon a specific, highly reductive conception of life, which sought to remove any distinction between living and non-living matter that could serve as an obstacle to the patenting of living but unnatural organisms. It would be easy to underestimate the philosophical, moral and ideological importance of the abolition of such a distinction, precisely because it allows a shift in accepted ideas as to what may be done to living things.

Recommendation

That the WCC maintain a watching brief on the issues arising from the patenting of micro-organisms.

B. Plants

Patenting of living plants has been introduced into many Western countries. Patenting gives the right of ownership of varieties or hybrids to corporations or firms including the exclusive rights for a number of years to propagate and market their products. Opponents of this legislation argue that this development will contribute

significantly to decrease of genetic diversity. The worldwide reduction of genetic variability in crops is already in large part a consequence of the widespread cultivation of the relatively few high-yielding varieties in the green revolution. The extensive cultivation of a limited number of genetically uniform varieties has led to a decrease in genetic diversity of a crop in a given area. Decreased genetic variability increases the vulnerability of crops to diseases and pests.

Corporations that own patents are in a monopoly position and are able to drive up the prices of their seeds. Moreover, corporations may enhance their power and control over the markets in which they operate through the production and marketing of those plants which are dependent on fertilizers and pesticides produced by themselves.

It is well known that many large seed firms are in possession of substantial genetic collections of genetic varieties of certain crops. It has been reported that in some cases they refuse to divulge information regarding the quantity and quality of what they possess. Reduced worldwide availability of genotypes of a particular crop can lead to increased dependences on the dominant corporations which hold the major genetic stocks of that crop.

Developing countries could:

a) become more conscious of their genetic treasures and make efforts to preserve them; national and regional programmes should be encouraged;
b) initiate efforts to breed varieties suitable for their own agro-climatic conditions rather than importing seeds.

In many countries there is a strenuous debate on the genetic and social consequences of plant patenting as more and more countries consider legislation on this subject. Plant breeders are themselves divided on this subject. There is a danger that control of the seed industries of the world by transnational corporations through plant patenting could be harmful to farmers. The involvement of the WCC in this issue would be consistent with its concern for the future of the world food supply.

Recommendations

1. That the WCC's programme on transnational corporations be asked to consider the likely implications of plant patenting by TNCs.

2. That the WCC convene a consultation to consider in detail the question of decreasing genetic diversity alleged by many to be a con-

sequence of plant patenting, and that the consultation also consider ways in which scientists and the public in developing countries could be made more aware of the importance of these issues.

C. Control and development of products derived from genetically modified micro-organisms

Genetically modified bacteria, yeasts and other micro-organisms will be useful for the production of substances needed for medical, pharmaceutical, agricultural and industrial purposes. Examples are the production of human insulin, human and livestock growth hormones, vaccines and ethanol.

Serious ethical and social concerns are raised by the control of the development of these new products. Private corporations often serve the interests of owners and managers to the disadvantage of the general public. Government and military agencies may equally serve the interest of the nation to the disadvantage of the rest of the world.

In a typical case in the USA a modified micro-organism will be patented by a corporation such as a pharmaceutical firm which will then own the living organism and have complete rights for the production and sale of its products. There is perhaps nothing intrinsically different in this from existing arrangements, such as those for the production and sale of penicillin where the process and not the product is protected by patent. But the likely extent of the new biotechnologies raises in an acute way the issue of private ownership of the production of products needed for human welfare. Similarly, government agencies may direct research and production towards the enhancement of national advantage in relation to other nations.

We are concerned that the availability of products which result from scientific endeavour may be restricted by the modes of marketing and distribution which could also influence the direction of future research and development. The present time is therefore critically appropriate for reconsideration of how products needed for human welfare can be made available for maximum benefit to the worldwide human community.

There is also reason to be concerned about the increasing tendency of scientific investigators in universities, and universities themselves, to take out patents on organisms they have helped to invent, and then to establish their own corporations for the production and sale of products from them. This is not consonant with the true role of a university which is to extend and communicate knowledge.

Alternative arrangements for the production and sale of the new products of biotechnology are possible and should be seriously discussed by communities and governments. For example, governments may control, as some now do, the rights to produce and sell these products. They may distribute these rights to selected groups or might retain complete control of the process. Churches and other institutions should press for alternative ways in which the labours of science are transmuted into the maximum human good. In some instances church groups could oppose monopoly power by TNCs in this field. In others they might be advised to withdraw their shares from corporations that abuse their control of particular biotechnologies. Churches should be particularly concerned about the use of some of these new biotechnologies in situations where such use would be inappropriate or even dangerous. For example, new micro-organisms and new plant varieties may be promoted for sale in regions for which they are not suited. However, unless good alternatives are clearly pointed out it may be difficult for people in these regions to resist the pressure to buy such ill-adapted products. At some stage a booklet could be usefully produced describing the new biotechnologies, for example in agriculture, their advantages, their dangers and possible alternatives.

5. Dialogue with scientists and others on the implications of the new biotechnologies

Ways and means of restructuring curricula to take account of the social, ethical, economic and political implications of the biotechnologies need to be explored. Model curricula could be publicized through cooperation between the WCC and university groups.

Schools and places of higher learning have need for video-cassettes and other means of discussing the social, ethical, economic and political implications of biotechnologies. Means need to be explored.

Churches will encounter a problem when they seek to enter into discussion with the scientific community on these issues. This is created by the image of the church as presented by some Christian groups or individuals who take anti-scientific or anti-evolutionary positions. These are often presented in the media as the Christian gospel. The WCC should consider ways of correcting such false images.

Recommendation

That the WCC consider ways by which the false image of the churches created by anti-scientific Christian groups might be countered.

6. Biological warfare

The rapid growth in techniques of bio-manipulation yields a potential for serious harm as well as for benefits to humankind. Future applications of these techniques could increase the effectiveness of biological weapons in terms of transportability, survival under field conditions, virulence and specificity for target human, animal and plant populations. In addition, the techniques could make possible cheaper and more efficient production of toxic chemicals for military use. Although these new techniques are felt by some to be unlikely to yield significant military advantages, that possibility cannot be ruled out in the future.

Use of biological and chemical weapons is prohibited by the Geneva Protocol of 1925. Development, production and stockpiling of biological weapons is forbidden by the Biological Weapons Convention of 1972. The latter treaty is assumed to cover *all* biological weapons, regardless of their method of development. Nevertheless, there remain serious grounds for concern about possible future use of biological weapons, and of weapons of biological origin:

— only half of the nations have signed the Bacteriological Warfare Convention;
— biological toxins and toxic chemicals synthesized using biological processes are not covered by the Convention;
— the line between chemical and biological weapons is not always well defined;
— the present deterioration in relations between some of the world's nations increases the danger that governments may begin to rationalize the need to develop and even use the weapons proscribed by the international treaties.

Recommendations

Of all hazards to life, war is by far the greatest. We therefore call on the Central Committee of the WCC to give the recommendations below their special attention:

1. The WCC should reaffirm support for the Biological Weapons Convention of 1972 and urge all nations to adopt it.

2. The WCC should reaffirm support for the Geneva Protocol of 1925 and urge all nations to adopt it and extend its coverage to prohibit the development, production and stockpiling of chemical weapons, including toxins and toxic chemicals synthesized through biological processes.

3. The WCC should call on scientists throughout the world not to participate in any research associated with the development and production of chemical and biological weapons.

We ask the Central Committee to send this statement to the member churches and to all national academies of science, to the International Council of Scientific Unions, and to the United Nations.

7. Summary of recommendations

1. That churches be invited to examine how they can contribute to the human subjects review process and to the work of national committees with advisory or regulatory responsibilities for genetic engineering (page 11).

2. That the Sub-unit on Church and Society be requested to take the necessary steps to encourage the appropriate agencies of the UN, including WHO, ILO, UNEP, UNESCO, to convene a conference to initiate the formation of international guidelines and regulations governing the development and use of bio-technologies (page 17).

3. That the churches be asked to work nationally and internationally to encourage mechanisms of participation that include affected and interested parties at all levels and stages of policy-making regarding bio-technology (page 17).

4. That the churches be asked to promote:

a) the ongoing health monitoring and risk assessment procedures for communities where these technologies are developed and used;

b) mechanisms that provide monitoring of environmental effects (page 17).

5. That the Sub-unit on Church and Society initiate a study with third world scientists and theologians of the spread of bio-technology in the third world to ascertain if therapies and products introduced fit the local cultural, economic and social needs (page 17).

6. That Church and Society maintain an ongoing working group on biological manipulation of life to monitor the rapidly developing bio-technology field and report their findings to the churches, and report initial findings to the next Assembly (page 17).

7. That the WCC maintain a watching brief on the issues arising from the patenting of micro-organisms (page 19).

8. That the WCC programme on transnational corporations be asked to consider the likely implications of plant patenting by TNCs (page 20).

9. That the WCC convene a consultation to consider in detail the question of decreasing genetic diversity alleged by some to be a consequence of plant patenting, and that the consultation also consider ways in which scientists and the public in developing countries could be made more aware of the importance of these issues (page 20).

10. That the WCC consider ways by which the image of the churches created by anti-scientific Christian groups might be countered (page 23).

11. That the WCC should reaffirm support for the Biological Weapons Convention of 1972 and urge all nations to adopt it (page 25).

12. That the WCC should reaffirm support for the Geneva Protocol of 1925 and urge all nations to adopt it and extend its coverage to prohibit the development, production and stockpiling of chemical weapons, including toxins and toxic chemicals synthesized through biological processes (page 25).

13. That the WCC should call on scientists throughout the world not to participate in any research associated with the development and production of chemical and biological weapons (page 25).

14. That this report be sent to the member churches and all national academies of science, to the International Council of Scientific Unions, and to the United Nations (page 25).

Appendix I
Ethical issues in experiments with hybrids of different species

Interspecific hybrids (hybrids between two different species) can be made in a number of different ways at different levels; some have already been undertaken, others are feasible but have not yet been attempted. Such experiments are made to provide information on how genes act in embryonic development. Already, the hybridization of individual cells of, for example, man and mouse is well established. Cells from the skin of each species are grown in culture and then one cell of one species is induced to fuse totally with the other. There is a complete mixing of the nuclear and cytoplasmic elements. The hybrid cell continues to grow in culture and with the passage of time some of both mouse and human chromosomes are extruded and lost until a "balanced" cell is achieved with a mixture of both mouse and human chromosomes and biochemical characteristics. Such experiments are limited to the test-tube and provide scientific information.

Another technique involves the hybridization of mouse and human tumour cells as above, and the transplantation of this hybrid cell into a very early mouse embryo, at a stage when the embryo is merely a microscopically small ball of cells. The hybrid cell is added to that clump of cells and as development proceeds it divides as do all the other cells and becomes fully integrated with the embryo. The embryo is introduced into the uterus of a mouse foster mother where it implants and grows to term as an ordinary conceptus would and is subsequently born. This new-born mouse has in its tissues some of the hybrid cells which bear some human chromosomes and some human-type proteins.

Of far more significance is the possibility not yet realized of creating complete hybrid individuals by the hybridization of human and a chimpanzee. This could be attempted by two techniques. First, the fertilization of a human egg by chimpanzee sperm or chimpanzee ovum by human sperm, either *in vitro* or *in vivo,* with the subsequent

development of the hybrid *in utero* to term. Nature has herself chemical mechanisms which prevent interspecific crosses of this type; furthermore should fertilization occur, chromosome imbalance would probably prejudice any long-term development. So it is probable that these biological controls would make such an experiment unsuccessful. However, exceptions do occur in nature, for example a horse and a donkey can hybridize to produce a mule, albeit a sterile creature; so until it has been tried, we cannot say for sure that man-chimpanzee hybrids of this type would not be successful.

The whole group of experiments described may throw some light on the problem of what it is that makes an individual a human whom we then want to protect in our moral deliberations. A few "manufactured" somatic cells growing in a test-tube for a time, which have a few human chromosomes and one or two human cytoplasmic proteins, and a live mouse with a small proportion of its cells containing a few human chromosomes and proteins are not considered experiments which should be prohibited. They have been done and there has been no outcry against them within the scientific community or the informed public. What is created by them has not thereby been rendered sufficiently "human" to warrant our protection. We are not shocked by these experiments. But there is a revulsion and abhorrence for the human-chimpanzee hybrid embryo experiments so that the group preparing this report suggests prohibition of these. Here we potentially create something which contains sufficient of that which we regard as human to demand our protection. What is it that renders it so? Is it the possession of cells which have the full complement of 46 human chromosomes? A normally fertilized human ovum also contains a full complement of human chromosomes, as do normal early human embryos, yet the many people in favour of abortion would not regard either of these as human and do not want to protect them. Is it rather that such a human/chimpanzee hybrid might contain in addition to the chromosomes sufficient of that which causes a being to live and move and think and feel as a human? Some people might want to call this the "soul", others "personality", others the "life force", and so on. Whatever this is, it is not an anatomical part which a scientist can identify by examination or dissection. It is rather a series of vital qualitative characters. It is probable that there is no fully scientific definition of what it is to be human, but it is more a composite of scientific *and* these other characters and qualities.

We are distressed by any person who does not manifest a complete set of human qualities and characters, e.g. mentally and physically handicapped people. Although we treat them with love and respect as we do any human being, everyone would wish that the handicapped were not so and that they had the entire spectrum of basic human attributes. To create artificially and knowingly an individual which has only, in part, human attributes, is totally undesirable and the wrong use of our creative powers. Our creative powers should be used for benefit and not for detriment.

Appendix II
When does individual human life begin?

A. A note from the Working Group

The question is commonly put in this form in debates on abortion. But this formulation of the question reveals a misunderstanding of both the nature of human embryonic development and the meaning of human life. It is a task for the churches to correct these misunderstandings and to put the question in a better form.

Human reproduction, like the reproduction of all living things, is basically a cyclical process. Because living cells arise only from other living cells, there is no step in the cycle where "life" can be said to begin. An unfertilized egg (which is a living cell) unites with a sperm to form a fertilized egg (another living cell) which then grows and divides by mitosis to generate a cell aggregate. Individual cells of this aggregate undergo differentiation and further multiplication in a highly controlled manner, to generate a fully developed human organism. The various physical properties that are characteristic of a developed human individual are acquired gradually and sequentially as part of this process of differentiation and multiplication which continues even after birth. This is true both of visible structures or organs (eyes, limbs, bones, etc.) and of functional properties such as breathing or heartbeat.

At the very early stages of development, the fate of individual cells within the embryo is not yet fully determined. Experiments have been performed on other mammals such as mice in which early embryos consisting of a few cells are treated with a digestive enzyme that separates the individual cells from one another. These cells can then be reaggregated with one another or with cells from another individual. The new aggregate, when implanted in a surrogate mother, can proceed to develop into a normal mouse. Thus at this stage the cells of the original aggregate might be said to constitute an individual, but the specific inter-relationships among cells that later characterize the whole organism (and which constitute the basis of its

organized nature) are not yet permanently established. What the cells of the original aggregate have in common is an identical genetic constitution, because they are descendants of a single fertilized egg.

Experimental biological science can contribute such a factual description but nothing further towards answering the question "When does individual human life begin?" Science cannot define a point in the process where the embryo acquires "humanness" in a legal, social or theological sense. Answers to that question must be provided from areas other than biological science, if they are to be given at all. To expect an answer from science alone would constitute scientism in its most dehumanizing form, which should be rejected by scientists and theologians alike. But science and theology together have a responsibility to find answers to the issues this question seeks to raise.

B. Statement by Prof. Charles Hartshorne

(from "God and Nature", *Anticipation*, No. 25, January 1979)

The following statements seem amply supported by science:

1. A fertilized egg is a single cell, while a human being in the full sense is an organized whole of many billions of cells, above all including a nervous system of a unique degree of complexity (according to some perhaps rivalled by the nervous systems of whales and dolphins). Thus a fertilized egg is only potentially human in the full value sense, and is separated from that value by a qualitative difference vaster than that between an adult human person and even the lowest vertebrates. (*Note added:* The first elements of the nervous system appear on the 18th day after conception, but the nerves do not function until much later.)

2. The fertilized egg has indeed, with one qualification, the chemical individuality (the DNA or genetic code) of a potential person. The qualification is that with identical twins not even this is true: such twins have the same code yet are two individuals. But what crass materialism to equate the chemical individuality of a person with the person! I say this not because the DNA is physical, but because the proximate physical basis of personality is not chemical but neural. Identical twins have the same chemistry, but it by no means follows and is certainly quite false that their nervous systems have the same structure. The DNA influences the development of this structure but so do several other sorts of factors. These are (a) stimuli furnished by the uterine or extra-uterine environment and non-neural parts of the body, and (b) various feelings and experiences as the foetus, infant, or child responds to the stimuli.

Appendix III
Action of the Central Committee

Action of the thirty-third meeting of the Central Committee of the World Council of Churches, Dresden, GDR, August 1981, on the report from the consultation on "Ethical and Social Issues in Genetic Engineering and the Ownership of Life Forms"

The Unit Committee requests the Central Committee to receive with appreciation the report from the consultation on "Genetic Engineering and the Ownership of Life Forms" and recommends that this report be commended to the member churches for study; that a letter be sent to the member churches, national academies of science and to specialized agencies of the United Nations calling their attention to the recommendations addressed to them in the report.

The Unit Committee notes that in accordance with the Central Committee decision of 1980 (Minutes, page 49) and the recommendations of the consultation itself, an Advisory Group has been formed to monitor the rapidly developing bio-technology field and that this Advisory Group will report their findings to the churches and to the next Assembly. ... The Advisory Group will do its work through correspondence and will not meet unless called upon by the Assembly Preparations Committee.

The Unit Committee recommends to the Central Committee that the report of the consultation and the further reports from the Advisory Group be regarded as a contribution to the preparation for the Assembly theme on "Jesus Christ — the Life of the World", especially in relation to the discussion of the "genetic manipulation of life".

The Central Committee accepted these recommendations.

Appendix IV
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Glossary

Amniocentesis	A technique used to enable prenatal diagnosis, whereby some of the fluid which bathes the developing baby in the uterus is withdrawn for examination.
Beta-thalassemia	A hereditary blood disorder.
Down's syndrome	A disorder sometimes also called "mongolism", involving mental retardation (moderate or severe) and certain characteristic physical features. It is caused by an extra chromosome.
E. coli, *Escherichia coli*	A bacterium normally found residing harmlessly in the human gut, and used extensively in recombinant DNA research.
Germ-line cells	Reproductive cells, as distinct from body cells.
in vitro	Literally "in glass", for example, in a test-tube.
Mapping genes	Determining the location of genes on chromosomes.
Positive eugenics	Deliberate breeding for selected desired traits (characters), as in cattle breeding.
Prenatal diagnosis	The diagnosis of disorders prior to birth.
Recombinant DNA technology (genetic engineering)	Strictly, the splicing together of genes of two unrelated organisms and their insertion into a host organism; but also used as a general term covering any direct physical manipulation of genetic material.
Sickle cell anaemia	A genetically determined anaemia, affecting principally people of African origin.
Somatic cells	Body cells, as distinct from reproductive cells.
Tay-Sachs disease	A hereditary disease involving progressive degeneration of the nervous system and blindness, with death in the first decade of life. It occurs almost exclusively amongst people of Ashkenazi-Jewish descent.

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